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Anomalies in the application of the cascaded knife-edge diffraction model

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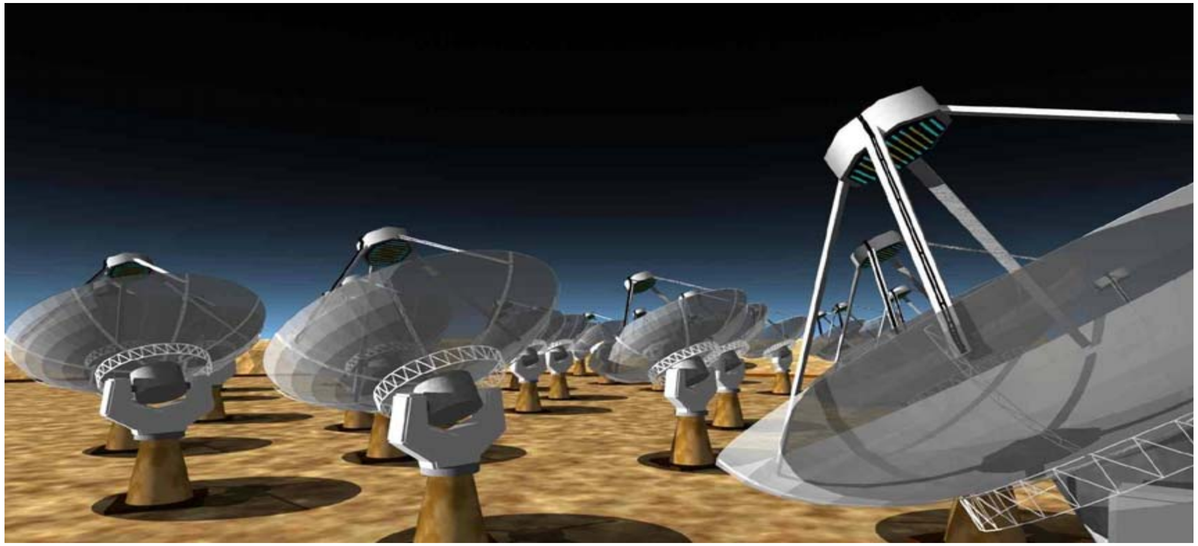
Outline of presentation

- Introduction: Motivation of study
- Anomalies in cascaded knife-edge method
  - Identification of problems
  - Source of problems
- Consideration of other methods and comparison of results

Motivation of study

- International collaboration in radioastronomy: Square Kilometre Array
- Host site: South Africa or Australia (decision in 2012)



- Establishment of radio-quiet zone in Western Australia
- Site for Australian SKA Pathfinder (ASKAP) telescope

Requirements of Radio Quiet Zone

- SKA: 100 MHz to 25 GHz
- ASKAP: 700 MHz to 1.8 GHz
- Maximum PSD at site
  - -214 dBm/Hz (100 MHz)
  - -228 dBm/Hz (1 GHz)
  - -236 dBm/Hz (25 GHz)
- Possible sources of interference:
  - Television (Perth 590 km, Geraldton 300 km)
  - Mining operations
  - Mobile communications
  - *Aircraft and satellite*
- Protection in legislation based on diffraction model in P.526

Specific analysis

- Possible interference near site, direction unknown
- Used cascaded knife-edge model from P.526
- Paths converging at telescope site, 0.5° apart
- At 2.3 GHz, discontinuity of up to 28 dB between radii
- Closer examination of paths 0.01° apart

Cascaded knife-edge diffraction model

- Used for prediction of signal level over long distances or wide areas
- Uses digital terrain map
- Simple to implement but surprisingly accurate compared to measurements
- Used by ITU-R for prediction of both wanted and interfering signals

Knife-edge diffraction model

- Terrain profile includes earth curvature and atmospheric refraction
- Diffraction parameter ν :

$$\nu_n = h\sqrt{2d_{ab}/\lambda d_{an} d_{nb}}$$

- Point with largest ν on entire path: principal edge
- Points with largest ν either side of principal edge: auxiliary edges

$$J(\nu) = 6.9 + 20\log\left(\sqrt{(\nu - 0.1)^2 + 1} + \nu - 0.1\right) \qquad \text{dB}$$

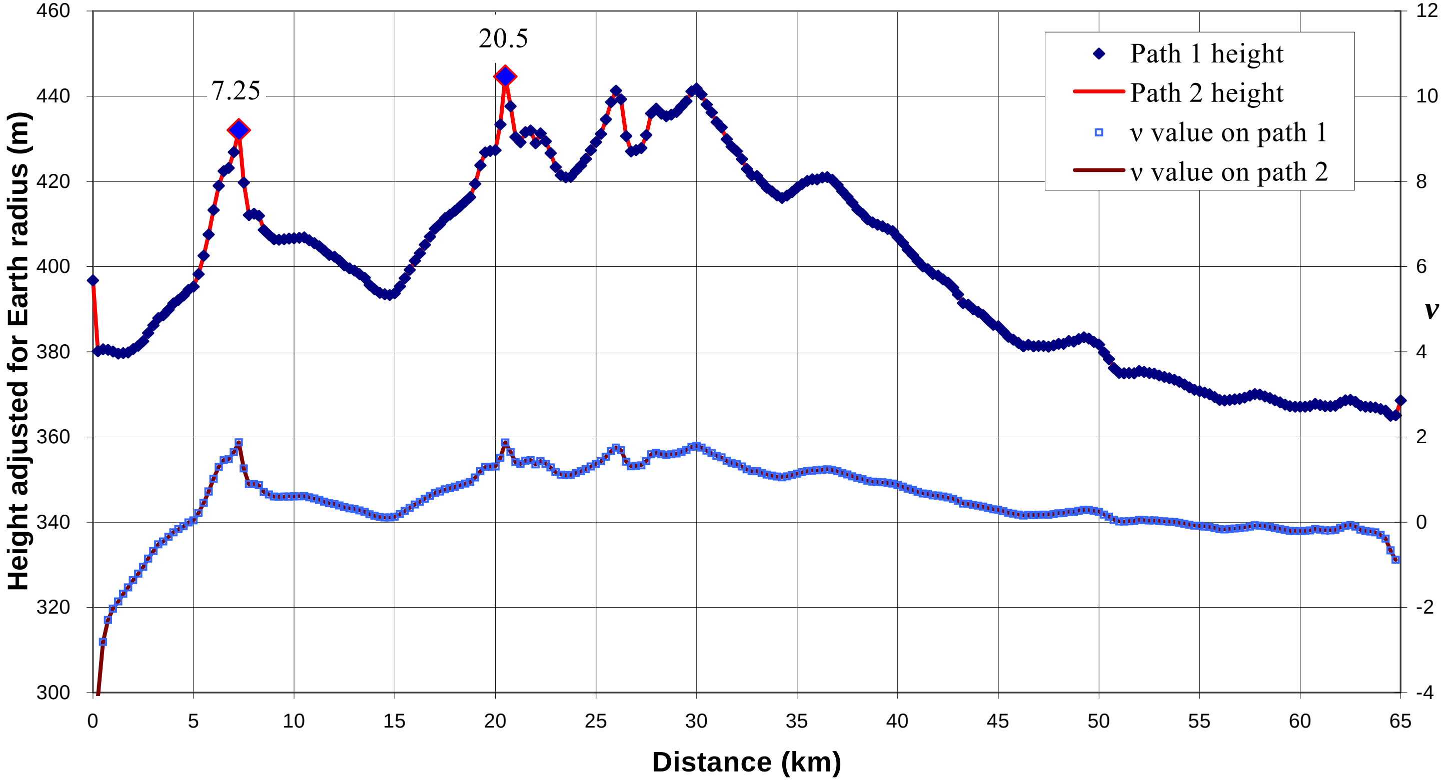
- Sum diffraction loss from three edges

$$L = J(\nu_p) + \left\{1.0 - \exp(-J(\nu_p)/6)\right\}[J(\nu_t) + J(\nu_r) + 10.0 + 0.04D]$$

Problem 1: “Jumping” principal edge

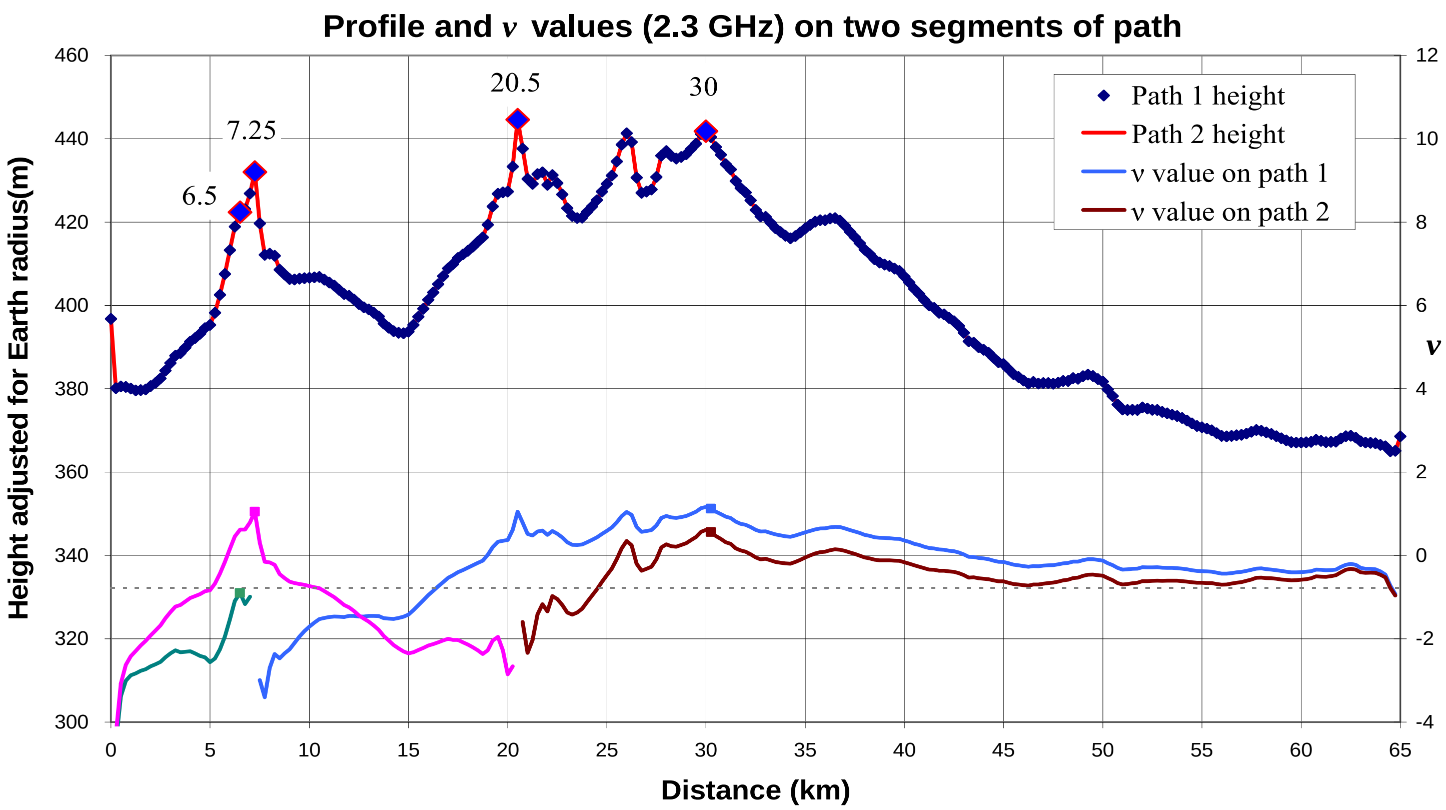
- In selecting the principal edge, if the <u>two</u> largest ν values are close, a small change in terrain can cause the principal edge to “jump” from one to the other. This affects the choice of auxiliary edges and the overall calculation of loss.

Profile and ν values (2.3 GHz) on whole path



Jumping – result on auxiliary edges

	ν at 7.25 km	ν at 20.5 km	Principal edge	$J(\nu_p)$	Auxiliary edge *t*	$J(\nu_t)$	Auxiliary edge *r*	$J(\nu_r)$	Total loss
Path 1	**1.8739**	1.8705	7.25 km	19 dB	6.5 km	0 dB	30 km	15 dB	45 dB
Path 2	1.8761	**1.8774**	20.5 km	19 dB	7.25 km	14 dB	30 km	11 dB	55 dB



Discontinuities due to effective Earth radius

- From ITU-R Recommendation P.526-10 [1]:

  "This method can produce discontinuities in predicted diffraction loss as a function of effective Earth radius due to different profile points being selected for the principal or auxiliary edges.

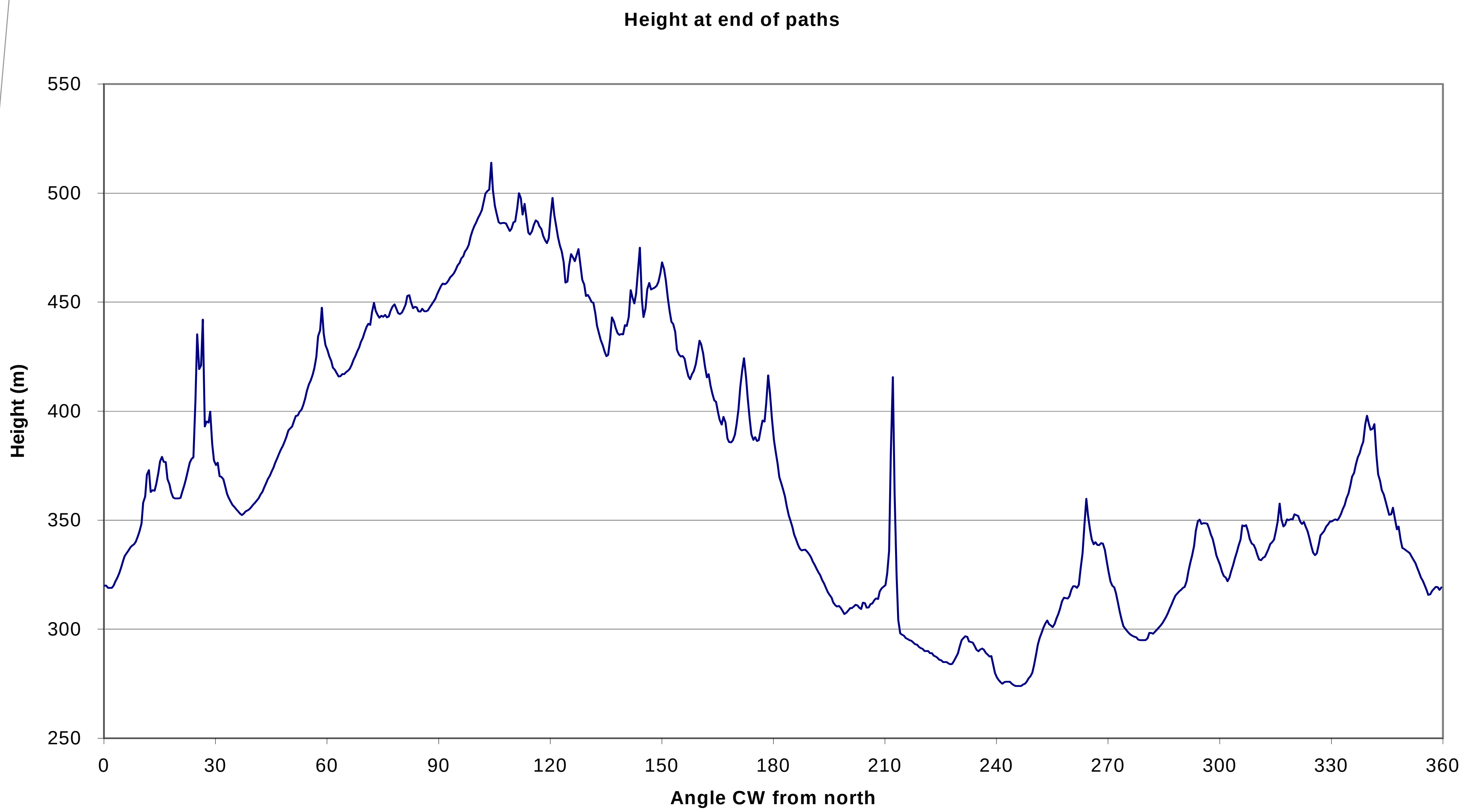
  To produce a smooth and monotonic prediction of diffraction loss as a function of effective Earth radius, the principal edge, and if they exist the auxiliary edges on either side, can first be found for median effective Earth radius.

  These edges can then be used when calculating diffraction losses for other values of effective Earth radius, without repeating the procedure for locating these points.

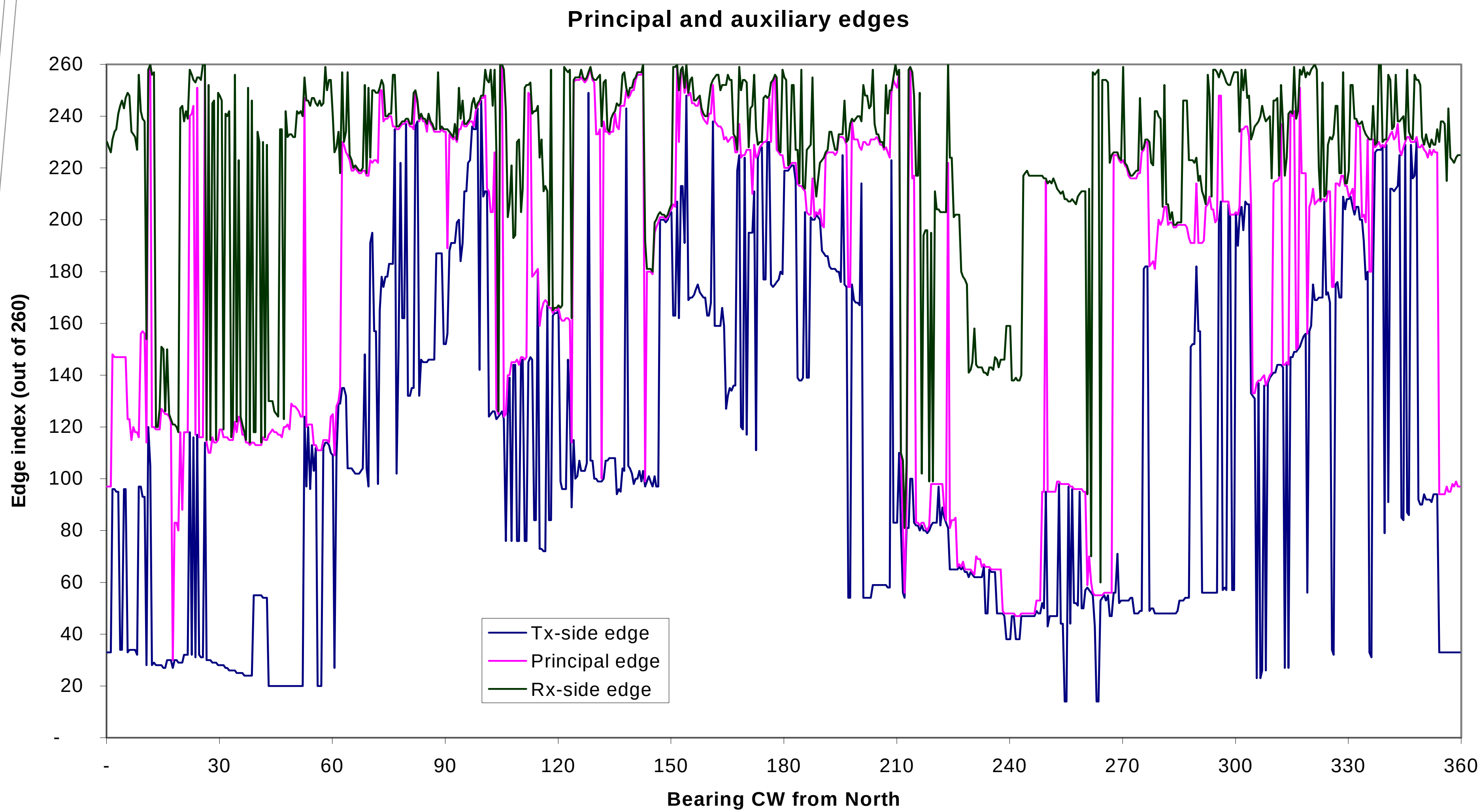
  However, this method may be less accurate at effective Earth radii greater than or less than the median value."

- For Earth radius, the median value serves as a reference point; there is no corresponding reference for changing terrain.

Height around circle



Edge instability



Problem 2: Missing edges?

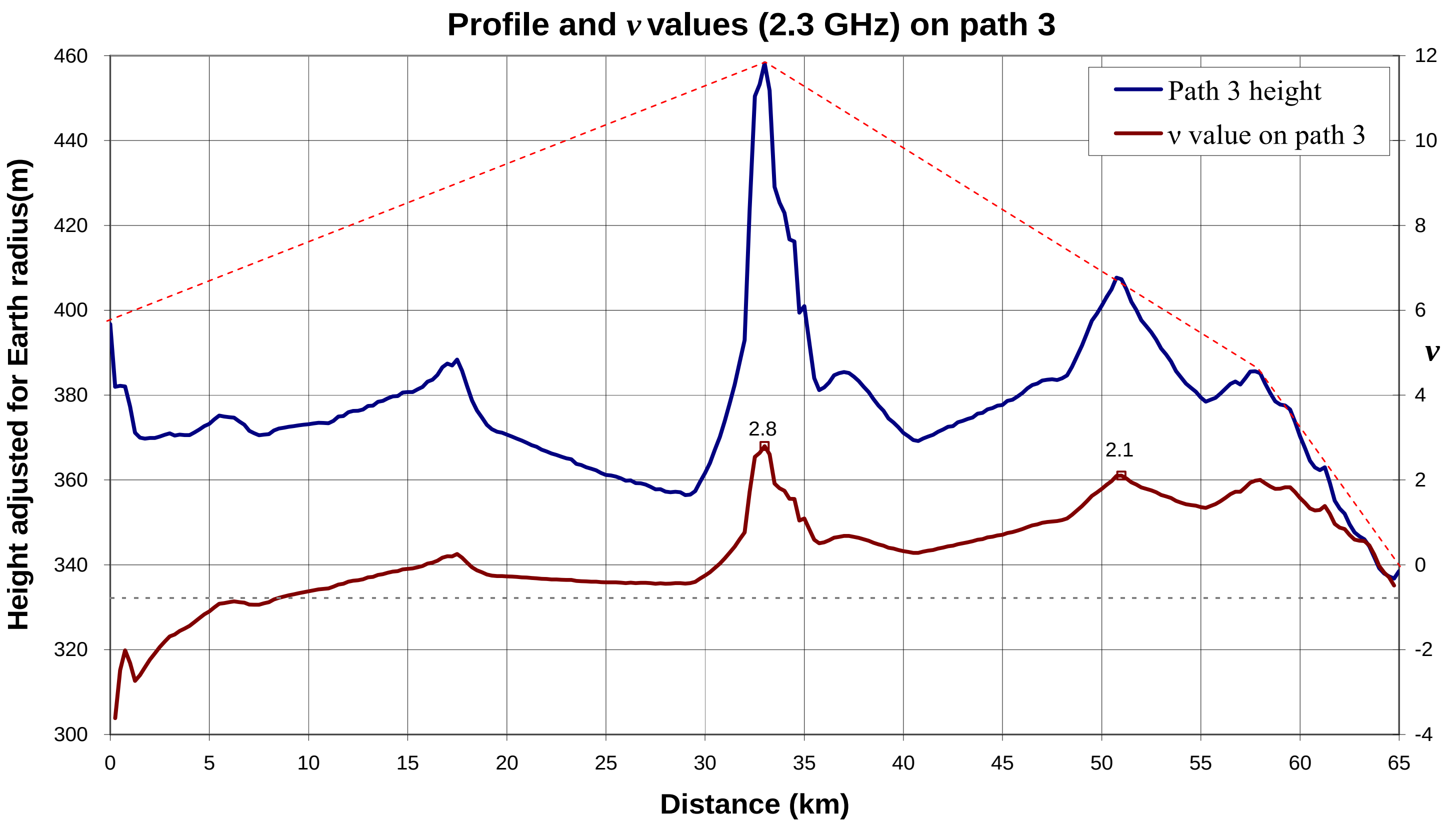
- Cascaded knife-edge algorithm: two auxiliary edges, one each side of principal edge.
- What if no significant obstruction on one side, but more than one on the other side?
- Algorithm selects an adjacent (or very close) point which is part of the same obstruction as one auxiliary point, and only one of the other obstructions as the second.

- Adjacent point typically adds about 6 dB to total path loss. Rounded obstacles produce more loss than sharp knife-edge. May be justified in many cases.

- What if adjacent point doesn't contribute but third obstruction is missed?

Overlooking the obvious?

	Principal edge	ν_p	$J(\nu_p)$	Auxiliary edge *t*	$J(\nu_t)$	Auxiliary edge *r*	$J(\nu_r)$	Total loss
Loss	33 km	2.8	22 dB	32.75 km	0	58 km	14 dB	48 dB



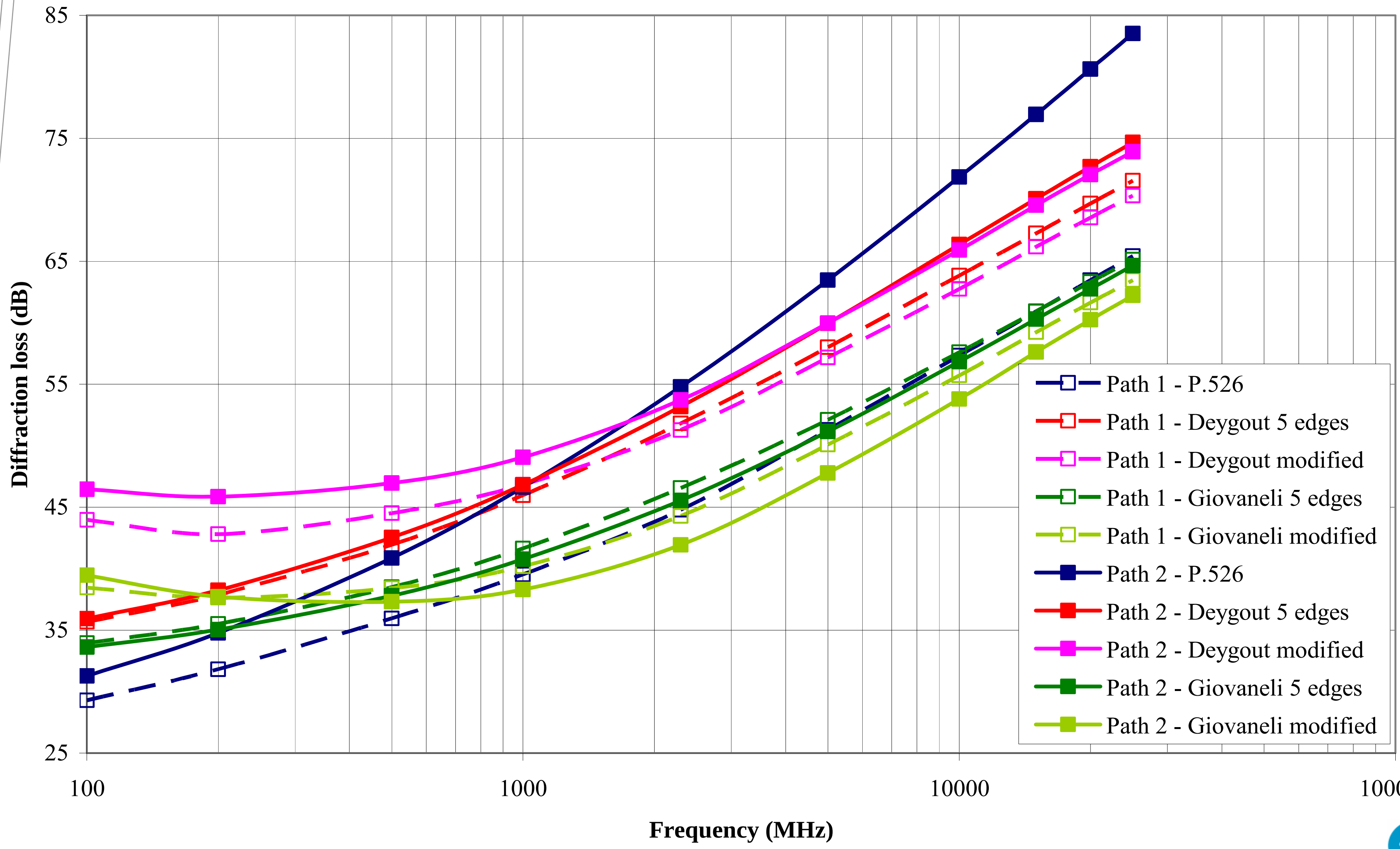
Is there a problem?

- Cascaded knife-edge diffraction algorithm based on Deygout’s work in 1966 [4]. 25 years later he wrote [5]:

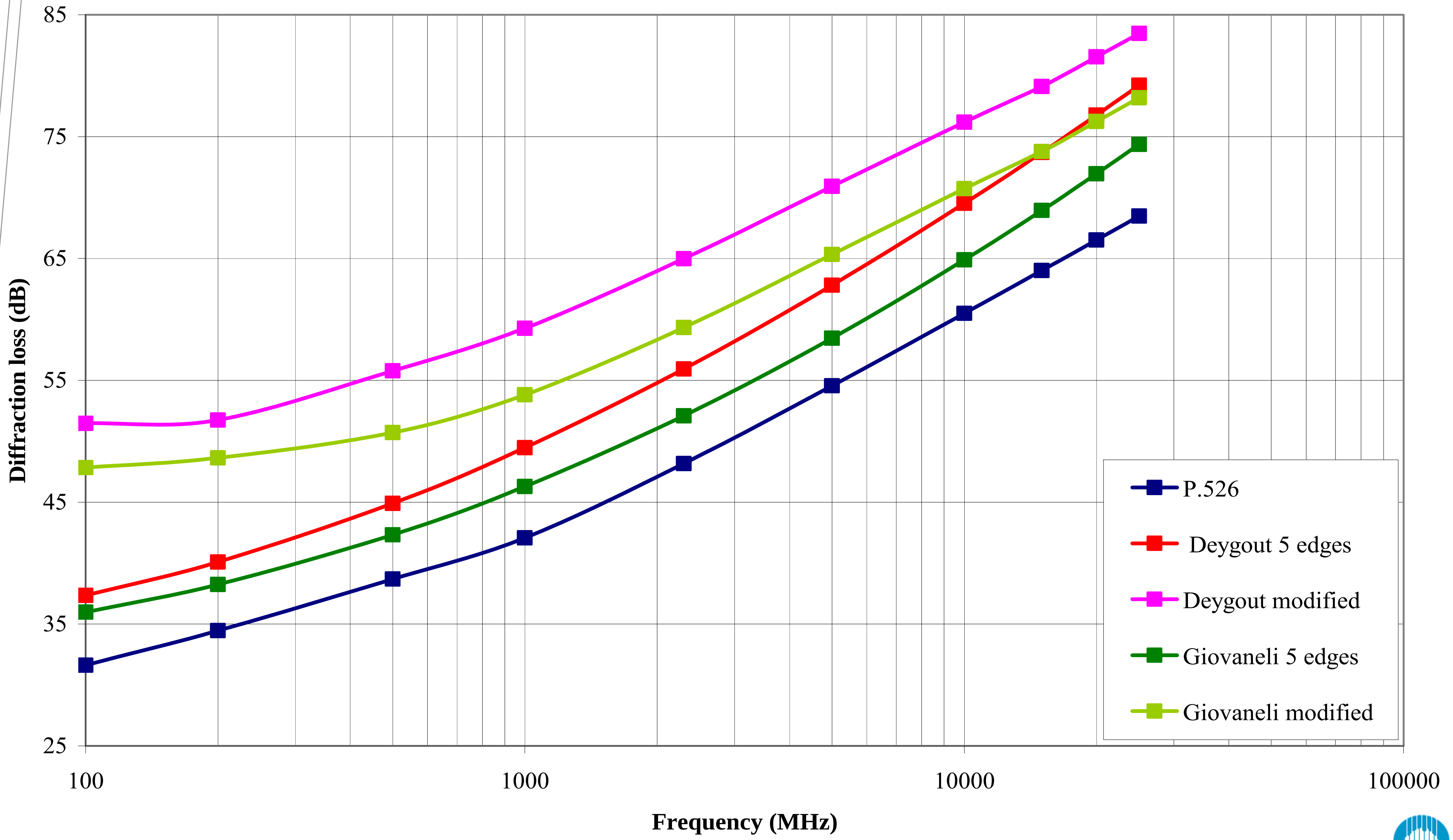
  “As long as one deals with maps and obtains full control of the profile by a glance, it is true that the correction is not mandatory because one selects only a few hills and it is certainly more secure to get a few decibels of extra margin, when one wants to establish a good link. It is a fact, however, that more extensive use of terrain databases can lead to unacceptable evaluation errors.”

- The anomalies seem to be such errors due to automatic searching rather than “selecting a few hills”.
- Limit of three edges seems to create problems.
- Principal edge loss evaluated without reference to other edges.

Other methods – Paths 1 and 2



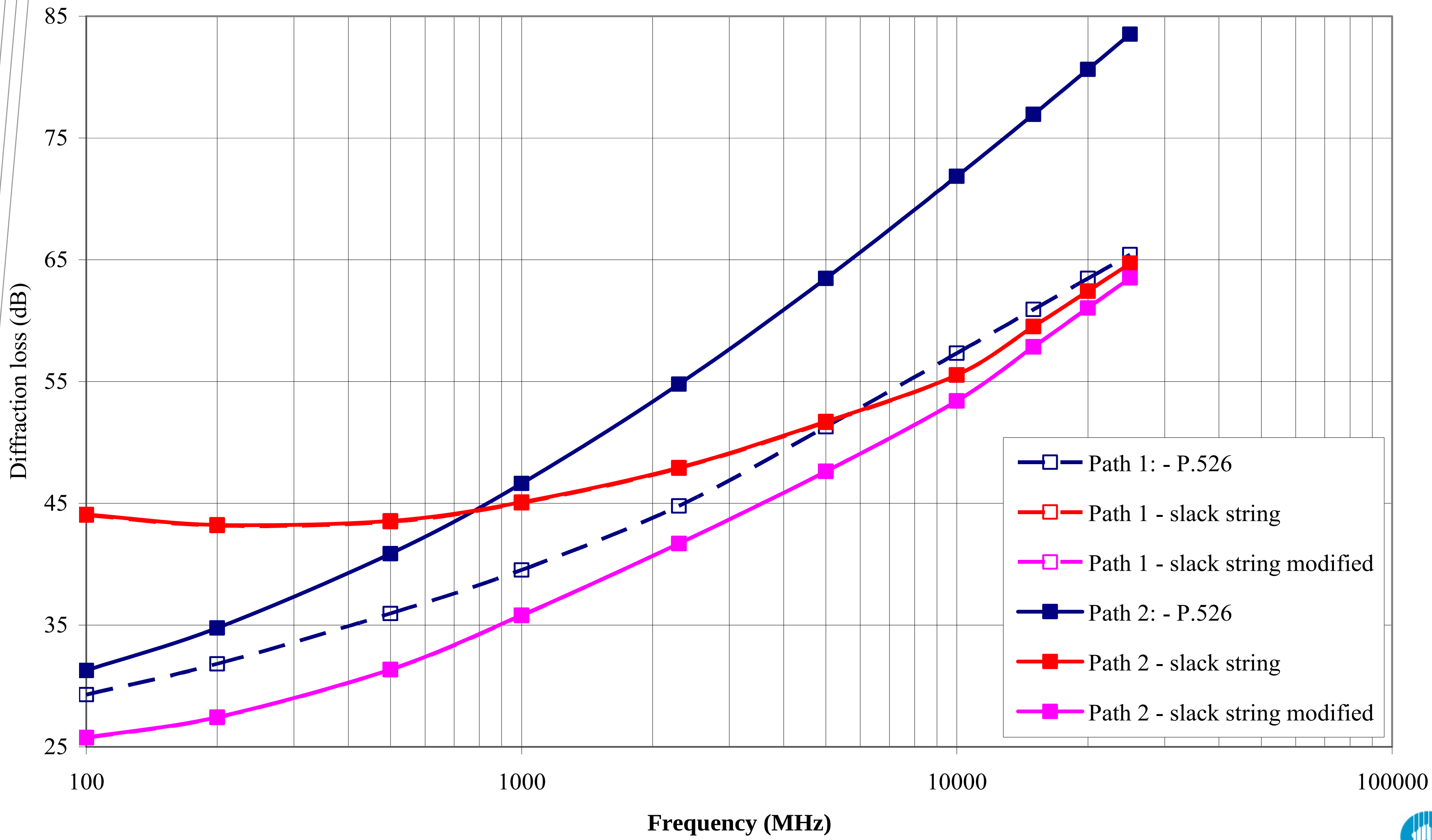
Other methods – Path 3



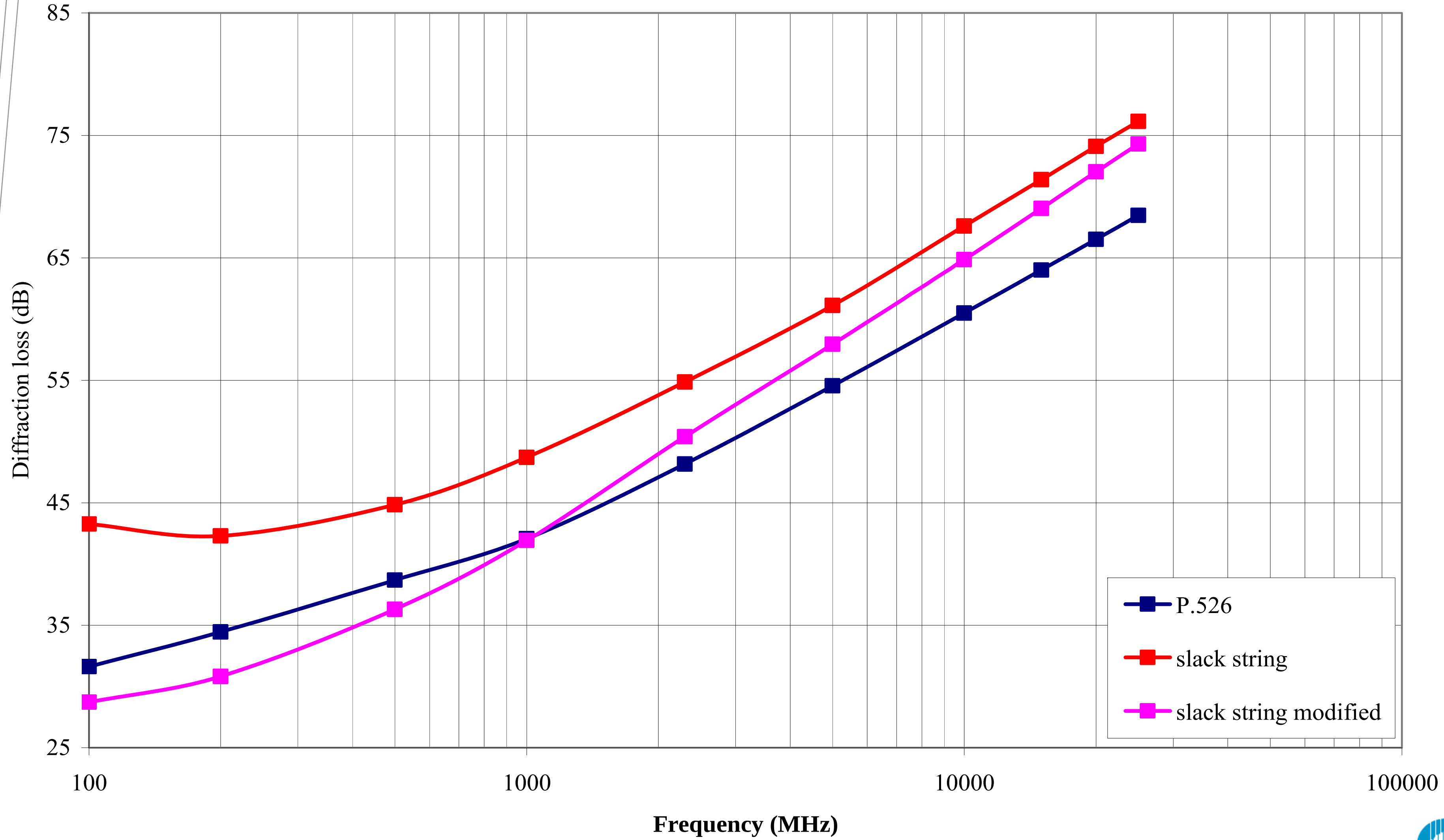
A way forward?

- Slack string model to be described in next paper
  - Use more edges
  - Transform “edge” to “slot”
  - Adjust loss at each edge by factor based on loss at adjacent edges
- Removes discontinuity with small terrain change
- Accounts for all edges

Slack string method – Paths 1 and 2



Slack string method – Path 3



Conclusions

- Need stable prediction method for regulatory control of interference at radio quiet zone
- Anomalies in cascaded knife-edge are problematic
- Other similar models do not completely address problems
- Need to consider Bullington as proposed for WP 3J
- Slack string model promising alternative

That's all folks!

Questions?

The authors gratefully acknowledge Hajime Suzuki, CSIRO, for the P.526 Matlab code.